

LOS ANGELES BASIN PROVINCE

by Scott D. Drewry

LOCATION

The Los Angeles Basin province is located offshore southern California from Point Dume (on the north) to Dana Point (on the south) (fig. 85). This Federal offshore assessment province is bounded on the north and east by the 3-mile line, on the west by the Palos Verdes fault zone, and on the south by the Dana Point sill (a basement high); it is approximately 70 miles long and 10 miles wide. The Palos Verdes Peninsula subdivides the province and its constituent plays into two noncontiguous subareas (one in the vicinity of Santa Monica Bay and one in the vicinity and south of San Pedro Bay), which together encompass an area of about 300 square miles. Water depth in the province ranges from about 100 to 2,000 feet.

GEOLOGIC SETTING

The province comprises the Federal offshore portion of the Los Angeles basin proper, a structurally controlled basin from which numerous oil fields produce onshore (fig. 86). The basin is considered to have formed by the clockwise rotation of the western Transverse Ranges. Rifting began in the early Miocene and resulted in relatively high heat flow and local isostatic uplift of basement blocks of the Catalina Schist.

Granitic rocks exposed east of the basin were a source of voluminous coarse clastic sediments that were deposited by late Miocene and early Pliocene fan systems (Puente and "Repetto"¹² Formations) in the basin (fig. 87). Much of the sediments were diverted into the southern (San Pedro Bay) subarea by uplifted basement blocks that effectively dammed the fans and modified their morphology. Numerous episodic pulses of fan deposition resulted in rapid burial and good reservoir potential. A regionally continuous basal organic shale ("nodular shale") is a prolific source of high-sulphur, low-gravity oil onshore; this unit (and possibly interbedded organic shales of the Puente Formation) may provide a rich petroleum source for the clastic fan reservoirs and the underlying breccia and schist

reservoirs offshore. Neogene strata in the Federal offshore portion of the Los Angeles basin have a maximum thickness of approximately 11,000 feet southeast of the Palos Verdes Peninsula and thin to the southeast.

The structural grain of the offshore part of the Los Angeles basin is dominated by the Palos Verdes and Newport-Inglewood fault zones. These northwest-trending fault zones appear to control the distribution of petroleum accumulations onshore and are presumed to be important migration paths and trapping mechanisms for accumulations offshore.

EXPLORATION AND DISCOVERY STATUS

Seismic-reflection data coverage is moderately dense to dense throughout the province; however, exploratory drilling has been restricted due to limited oil and gas leasing opportunities in State and Federal waters. In the northern (Santa Monica Bay) subarea, only two exploratory boreholes have been drilled; data from these boreholes—together with some data from approximately 20 boreholes in adjacent State waters—were considered for this assessment. Approximately 40 boreholes (including shallow coreholes and deeper wells) have been drilled in the southern (San Pedro Bay) subarea; approximately 50 boreholes have been drilled in adjacent State waters.

Although numerous oil fields exist in the onshore part of the Los Angeles basin, only two fields (Beta and its northwest extension) have been discovered in the Federal offshore area. Production from the Beta field began in 1981 and was ongoing as of this assessment with portions of the field under waterflood.

PLAYS

Two petroleum geologic plays have been defined and assessed in the province (figs. 86 and 87). The Puente Fan Sandstone play is an established play that includes middle Miocene to lower Pliocene sandstone reservoirs (Puente and Repetto Formations). The San Onofre Breccia play is a frontier play that includes lower to middle Miocene clastic reservoirs and underlying Cretaceous fractured schist reservoirs. Together, these plays essentially compose the Federal offshore extension of the onshore and State offshore Southwestern Shelf play, which has been defined and assessed by the U.S. Geological Survey (Beyer, 1995).

¹² The U.S. Geological Survey has abandoned the term "Repetto" (originally used to describe rocks that were deposited during the Repettian Stage) (Keroher and others, 1966); however, the term is widely used by the geological community and is used in this report.

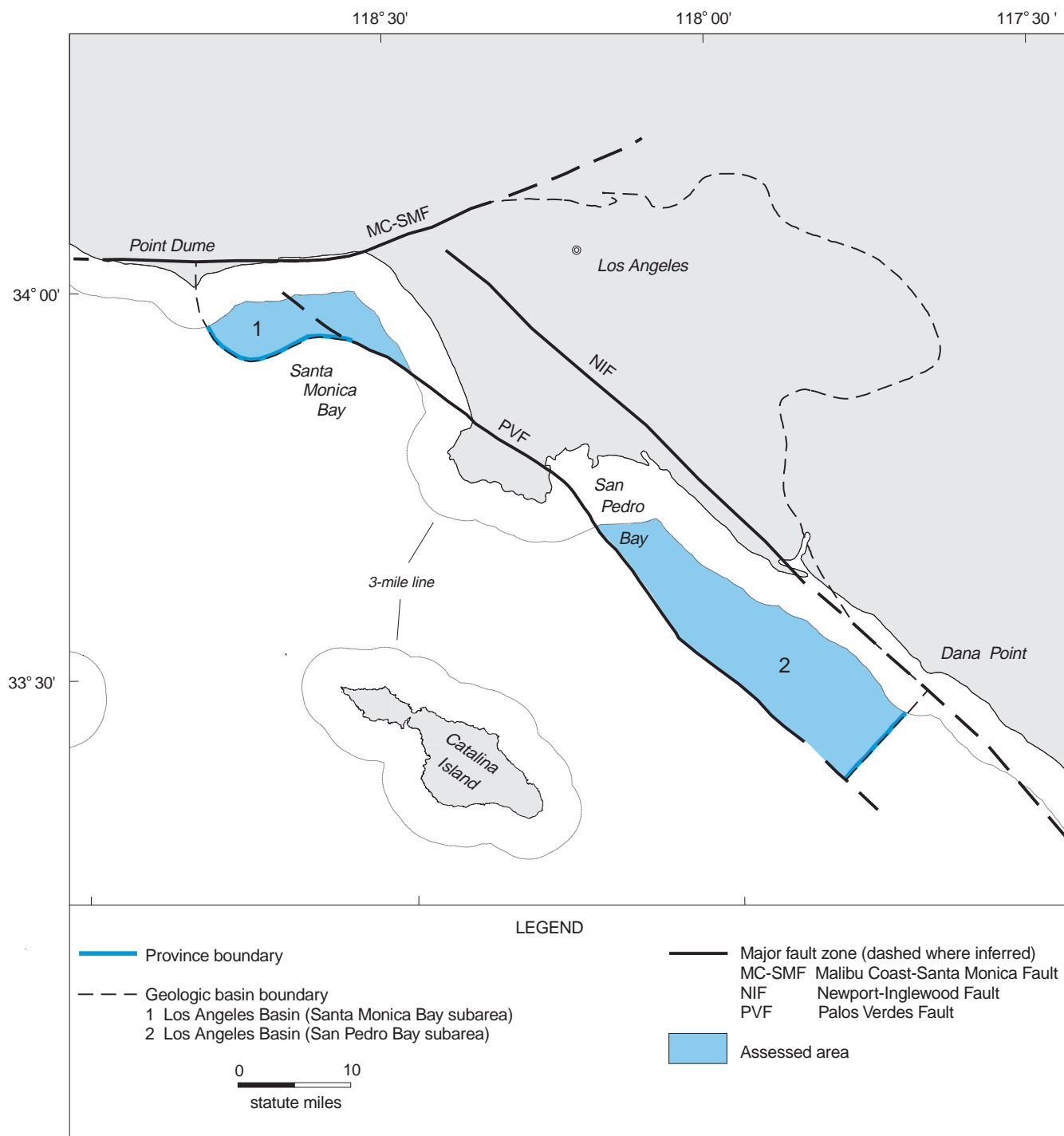


Figure 85. Map of the Los Angeles Basin province showing the geologic basin and assessed area.

RESOURCE ESTIMATES

Undiscovered Conventionally Recoverable Resources

Play-specific estimates of undiscovered conventionally recoverable resources have been developed using the subjective assessment method, and these estimates have been statistically aggregated to

estimate the total volume of resources in the province. Select data used to develop the resource estimates are shown in appendix C.

As a result of this assessment, the total volume of undiscovered conventionally recoverable resources in the Los Angeles Basin province is estimated to be 315 MMbbl of oil and 322 Bcf of associated gas

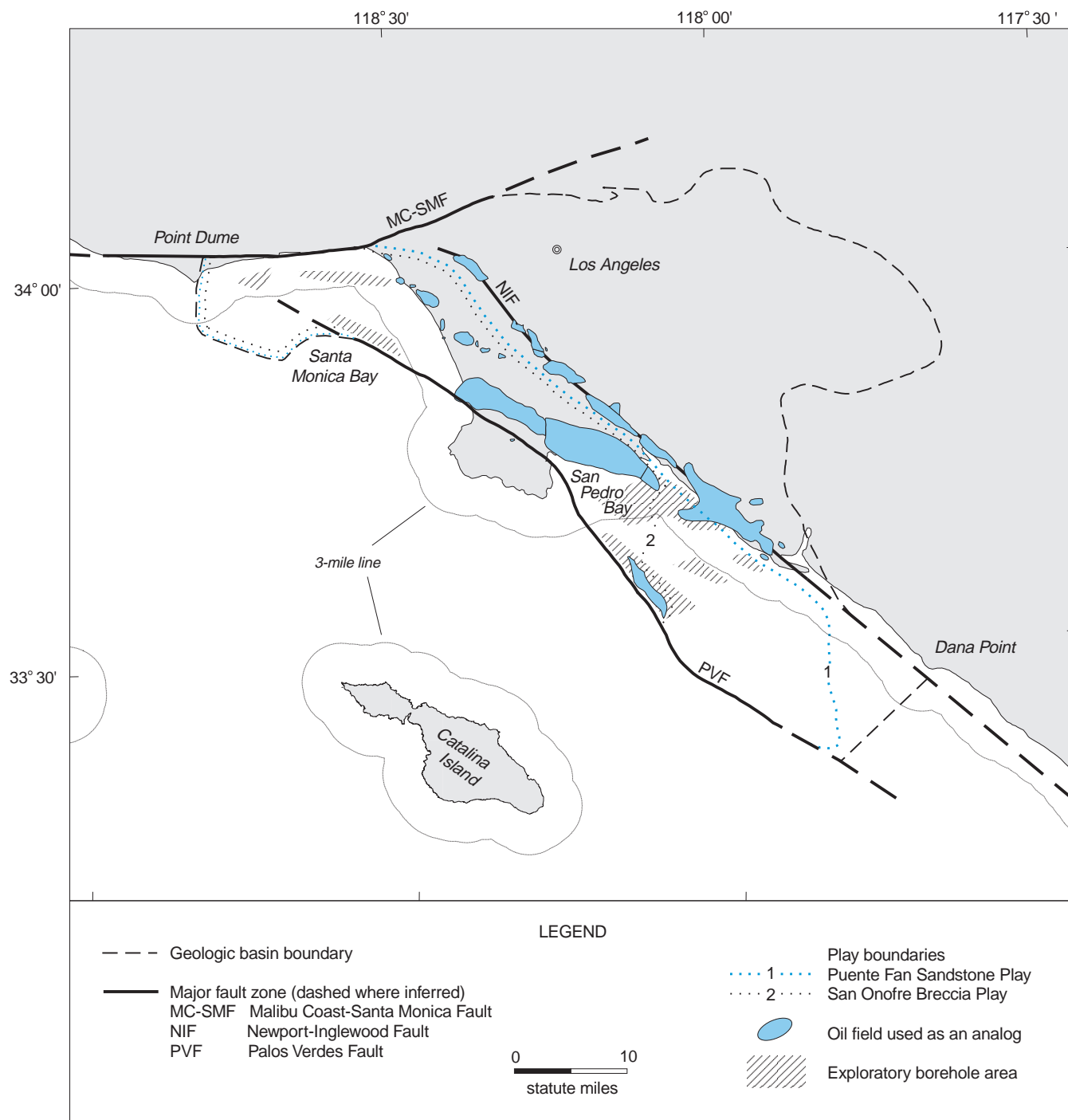


Figure 86. Map of the Los Angeles Basin province showing petroleum geologic plays, select fields, and borehole areas.

(mean estimates). This volume may exist in 21 fields with sizes ranging from approximately 380 Mbbl to 90 MMbbl of combined oil-equivalent resources (fig. 88). The majority of these resources (approximately 89 percent on a combined oil-equivalence basis) are estimated to exist in the Puebla Fan Sandstone play. The low, mean, and high estimates of resources in the province are listed in table 26 and illustrated in figure 89.

Undiscovered Economically Recoverable Resources

Estimates of undiscovered conventionally recoverable resources in the province that may be economically recoverable under various economic scenarios have been developed using the economic assessment method. Select data used to develop the resource estimates are shown in appendix D.

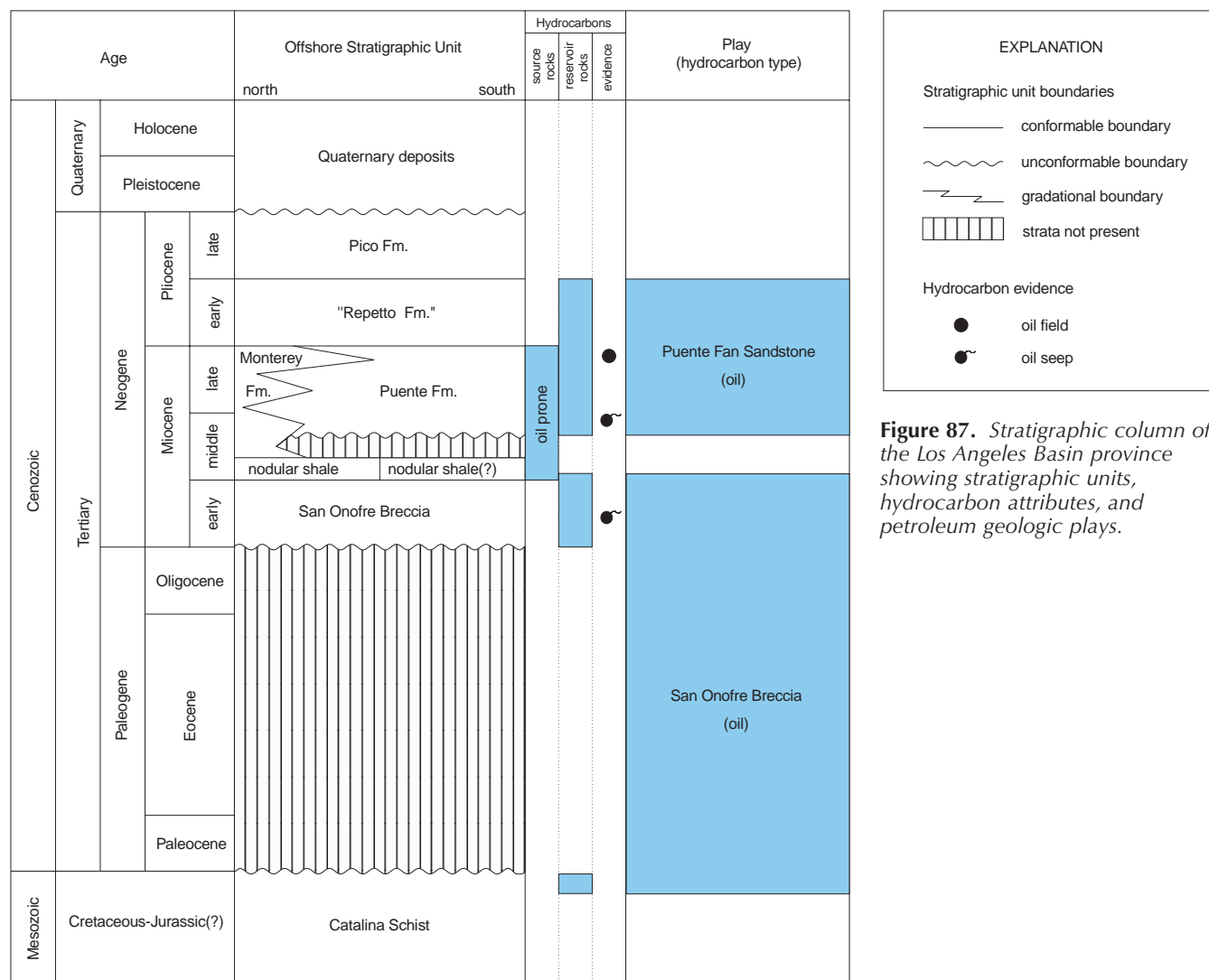


Figure 87. Stratigraphic column of the Los Angeles Basin province showing stratigraphic units, hydrocarbon attributes, and petroleum geologic plays.

As a result of this assessment, 209 MMbbl of oil and 213 Bcf of associated gas are estimated to be economically recoverable from the Los Angeles Basin province under economic conditions existing as of this assessment (i.e., the \$18-per-barrel economic scenario) (table 27). Larger volumes of resources are expected to be economically recoverable under increasingly favorable economic conditions (fig. 90).

Total Resource Endowment

As of this assessment, cumulative production from the province was 67 MMbbl of oil and 22 Bcf of gas; remaining reserves were estimated to be 55 MMbbl of oil and 11 Bcf of gas. These discovered resources (all from the Puente Fan Sandstone play) and the aforementioned undiscovered conventionally recoverable resources collectively compose the province's estimated total resource endowment of 437 MMbbl of oil and 355 Bcf of gas (table 28).

ACKNOWLEDGMENTS

This assessment of the Los Angeles Basin province was significantly enhanced by the contributions of many persons; most notably, Larry Beyer, Thane McCulloh, and Tom Wright gave generously of their time and experience. Acknowledgment is also due to Dennis Tayman and Scott Cranswick who performed the seismic interpretive mapping of the area.

ADDITIONAL REFERENCES

Beyer, 1988
 Crouch, 1990
 Crouch, Bachman, and Associates, Inc., 1989a
 Crouch and Suppe, 1993
 Redin, 1991
 Wright, 1991

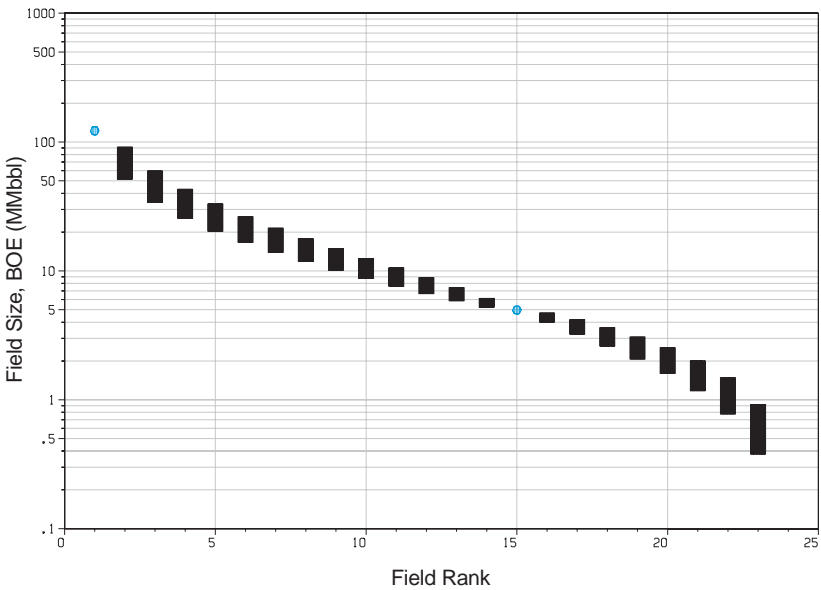


Figure 88. Field-size rank plot of estimated conventionally recoverable resources of the Los Angeles Basin province. Sizes of discovered fields are shown by dots. Sizes of undiscovered fields are shown by bars; the top and bottom of a bar represent the 25th- and 75th-percentile value of a probability distribution, respectively.

Table 26. Estimates of undiscovered conventionally recoverable oil and gas resources in the Los Angeles Basin province as of January 1, 1995, by play. All estimates are risky values. The low, mean, and high estimates correspond to the 95th-percentile, mean, and 5th-percentile values of a probability distribution, respectively. Percentile values are not additive; some total mean values may not equal the sum of the component values due to independent rounding.

Play	Oil (MMbbl)			Gas (Bcf)			BOE (MMbbl)		
	Low	Mean	High	Low	Mean	High	Low	Mean	High
Puente Fan Sandstone	171	277	447	161	306	516	202	331	531
San Onofre Breccia	0	38	96	0	16	44	0	41	104
Total Province	186	315	489	173	322	534	220	372	578

Figure 89. Cumulative probability plot of estimated undiscovered conventionally recoverable resources of the Los Angeles Basin province.

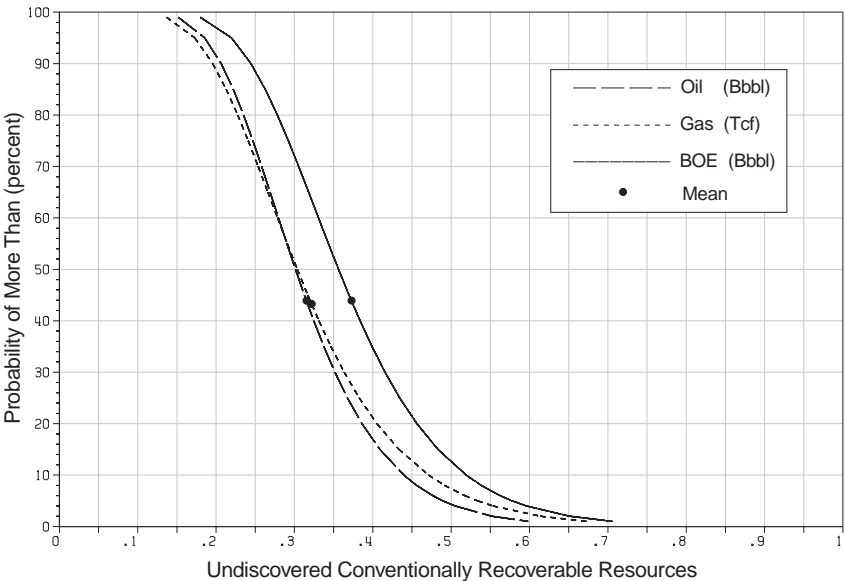


Table 27. Estimates of undiscovered economically recoverable oil and gas resources in the Los Angeles Basin province as of January 1, 1995, by economic scenario. All estimates are risked mean values. The \$18-per-barrel scenario is based on prices of \$18 per bbl of oil and \$2.11 per Mcf of gas; the \$25-per-barrel scenario is based on prices of \$25 per bbl of oil and \$2.94 per Mcf of gas; the \$50-per-barrel scenario is based on prices of \$50 per barrel of oil and \$5.87 per Mcf of gas.

Economic Scenario	Oil (MMbbl)	Gas (Bcf)	BOE (MMbbl)
\$18 per barrel	209	213	246
\$25 per barrel	242	247	286
\$50 per barrel	279	285	330

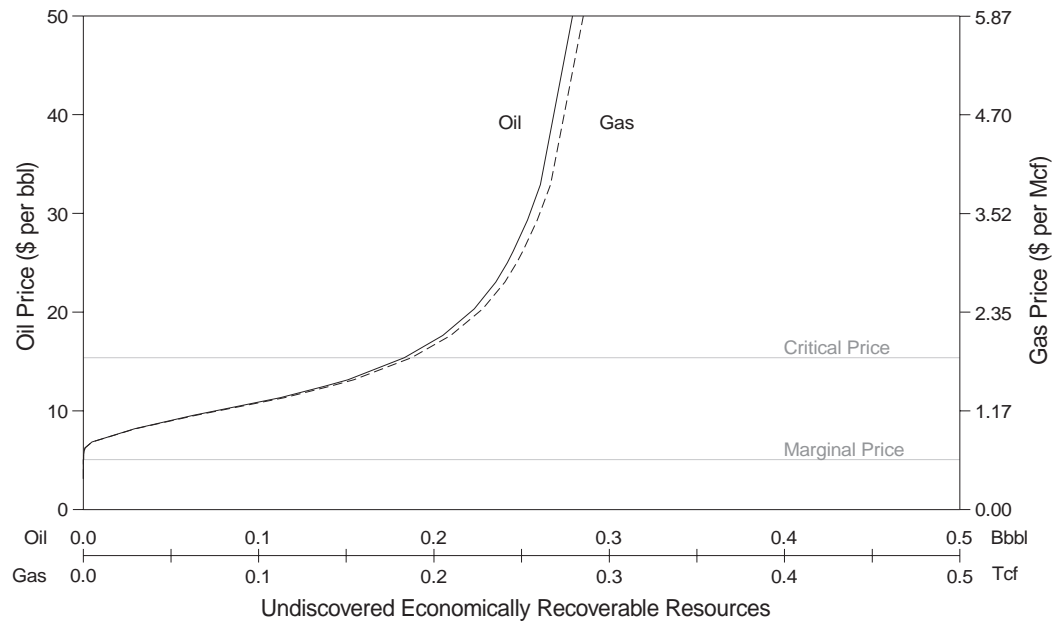


Figure 90. Price-supply plot of estimated undiscovered economically recoverable resources of the Los Angeles Basin province.

Table 28. Estimates of the total endowment of oil and gas resources in the Los Angeles Basin province. Estimates of discovered resources (including cumulative production and remaining reserves) and undiscovered resources are as of January 1, 1995. Estimates of undiscovered conventionally recoverable resources are risked mean values. Some total values may not equal the sum of the component values due to independent rounding.

Resource Category	Oil (Bbbl)	Gas (Tcf)	BOE (Bbbl)
Cumulative Production	0.07	0.02	0.07
Remaining Reserves	0.06	0.01	0.06
Undiscovered Conventionally Recoverable Resources	0.31	0.32	0.37
Total Resource Endowment	0.44	0.36	0.50

PUENTE FAN SANDSTONE PLAY

PLAY DEFINITION

The Puente Fan Sandstone play of the Los Angeles Basin province is defined to include accumulations of oil and associated gas in middle Miocene to lower Pliocene sandstones (Puente and Repetto Formations) in a variety of structural traps. The play exists west of the Newport-Inglewood fault zone and extends from Point Dume to the Dana Point sill (fig. 86). The Federal offshore portion of the play encompasses a total area of approximately 275 square miles. Depth to the main reservoir section (Puente Formation) ranges from 2,000 to 3,000 feet below the seafloor in the northern subarea; in the southern subarea, reservoir depths average from 4,000 to 5,000 feet below the seafloor.

The petroleum potential of the onshore and State offshore portions of this play has been assessed as part of the Southwestern Shelf play by the U.S. Geological Survey (Beyer, 1995).

PETROLEUM GEOLOGIC CHARACTERISTICS

Petroleum source rocks for this play include the lower middle Miocene "nodular shale" and interbedded middle Miocene pelagic mudstones and shales of the Puente Formation (fig. 87). Onshore,

these rocks are rich in marine-derived kerogen; total organic carbon content averages 4 percent and is as high as 10 and 16 percent in the "nodular shale" and Puente Formation, respectively (Jeffrey and others, 1991). High heat flow in the Los Angeles basin has generated oil from these kerogens at depths as shallow as 8,000 feet; the oil typically has moderately low gravity (less than 25 °API) and high sulphur content (greater than 1 percent). Oil gravity often increases with depth; this underscores the importance of identifying traps with possible migration pathways to deeper generative centers onshore (a limited migration distance).

Reservoir rocks for this play are middle Miocene to lower Pliocene sandstones of the Puente and Tarzana fans (Puente and Repetto Formations) (fig. 87). The structurally confined nature of the Los Angeles basin (i.e., bounded on the west by the Palos Verdes high) and the prolific granitic source combined to make these "distal" fan sandstones good to very good reservoir rocks; porosities in producing reservoirs offshore (Beta field) and onshore range from 17 to 33 percent (Crouch, 1990; Sorensen and others, 1993).

Traps in this play are predominantly faults and faulted anticlines along the Palos Verdes fault zone. Seals may be provided by interbedded pelagic and hemipelagic siltstones and shales.

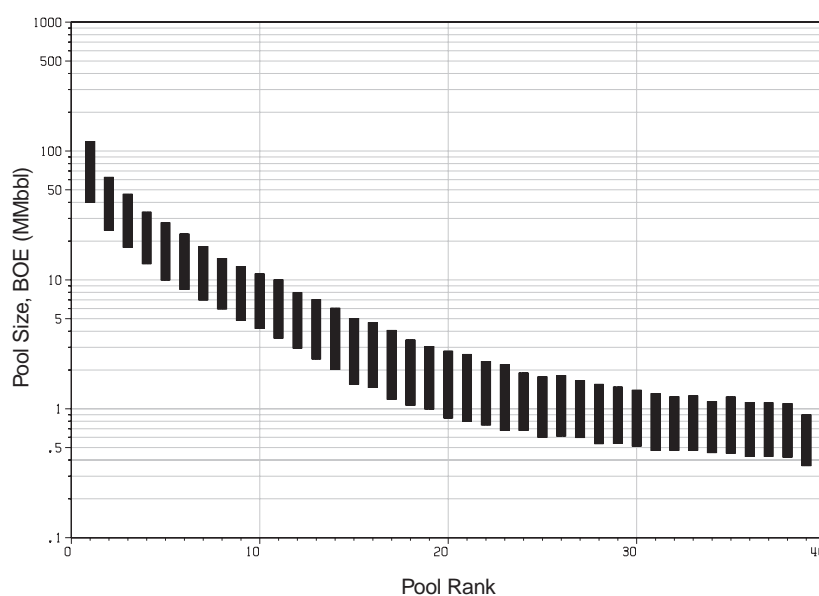


Figure 91. Pool-size rank plot of estimated undiscovered conventionally recoverable resources of the Puente Fan Sandstone play, Los Angeles Basin province. Sizes of undiscovered pools are shown by bars; the top and bottom of a bar represent the 25th- and 75th-percentile values of a probability distribution, respectively.

EXPLORATION AND DISCOVERY STATUS

Both of the coreholes drilled in the northern subarea penetrated rocks of this play; gas shows were noted in one corehole and tar was encountered in the other. Offshore oil seeps in the northern subarea suggest that onshore productive trends extend offshore. Most of the wells and coreholes in the southern subarea penetrated and encountered oil shows in rocks of this play.

Two fields (Beta and its northwest extension) have been discovered in the southern subarea of this established play. Production from the Beta field began in 1981 and was ongoing as of this assessment with portions of the field under waterflood. Numerous fields have been discovered in the adjacent State offshore and onshore areas; as of this assessment, approximately 8 Bbbl of oil have been produced from geologically analogous reservoir rocks in these fields.

RESOURCE ESTIMATES

Undiscovered Conventionally Recoverable Resources

Estimates of undiscovered conventionally recoverable resources in the Federal offshore portion of the play have been developed using the subjective assessment method with play-specific (Beta field) data and adjusted onshore analogs. Select data used to develop the resource estimates are shown in appendix C.

As a result of this assessment, the Federal offshore portion of the play is estimated to contain 277 MMbbl of oil and 306 Bcf of associated gas (mean estimates). This volume of undiscovered conventionally recoverable resources may exist in as many as 39 pools with sizes ranging from approximately 360 Mbbl to 120 MMbbl of combined oil-equivalent resources (fig. 91). The low, mean, and high estimates of resources in the play are listed in table 26.

SAN ONOFRE BRECCIA PLAY

PLAY DEFINITION

The San Onofre Breccia play of the Los Angeles Basin province is defined to include accumulations of oil and associated gas in stratigraphic and structural traps of the fractured Catalina Schist, schist-derived San Onofre Breccia, and overlying "nodular shale." The play exists west of the Newport-Inglewood fault zone in the northern two-thirds of the basin and extends from Point Dume to about 10 miles south of the Palos Verdes Peninsula (fig. 86). The Federal offshore portion of the play encompasses a total area of approximately 100 square miles. Depth to the reservoir section ranges from 2,000 to 7,000 feet below the seafloor in the northern subarea and from 7,000 to 11,000 feet in the southern subarea.

The petroleum potential of the onshore and State offshore portions of this play has been assessed as part of the Southwestern Shelf play by the U.S. Geological Survey (Beyer, 1995). Reservoir rocks equivalent to those included in this play are presumed to extend west of this play and have been assessed as the San Onofre Breccia play of the Santa Monica-San Pedro assessment area (see this report).

PETROLEUM GEOLOGIC CHARACTERISTICS

The petroleum source rock for this play is the lower middle Miocene "nodular shale" (fig. 87). Onshore, these rocks are rich in marine-derived

kerogen; total organic carbon content averages 4 percent and is as high as 10 percent (Jeffrey and others, 1991). High heat flow in the Los Angeles basin has generated oil from these kerogens at depths as shallow as 8,000 feet. The oil typically has moderately low gravity (less than 25 °API) and high sulphur content (greater than 1 percent). Oil gravity often increases with depth; this underscores the importance of identifying traps with possible migration pathways to deeper generative centers onshore (a limited migration distance).

The primary reservoir rocks for this play are lower Miocene sandstones and breccias of the San Onofre Breccia (Catalina Schist eroded from the Palos Verdes paleohigh) and locally fractured Cretaceous and possibly Jurassic rocks of the Catalina Schist. The lowermost and possibly fractured portion of the "nodular shale" may contain potential reservoir rocks and is also included in this play (fig. 87). Reservoir quality may be variable; porosities of analogous reservoirs onshore range from 12 to 31 percent.

Faults and pinchouts against local basement irregularities may produce many traps in this play; however, the traps must be located within the "sediment halo" of the Palos Verdes paleohigh to be considered viable targets. The overlying "nodular shale" may provide a seal as well as a petroleum source for the traps. The traps are expected to be small; the productive area of onshore analog fields ranges from 15 to 600 acres.

EXPLORATION AND DISCOVERY STATUS

Both of the coreholes drilled in the northern subarea penetrated rocks of this play; gas shows were noted in one corehole and tar was encountered in the other. Offshore oil seeps in this area may indicate that onshore productive trends (e.g., El Segundo, Playa Del Rey, and Venice Beach fields) extend offshore. Many of the wells and coreholes drilled in the southern subarea penetrated rocks of this frontier play; shows were encountered in a few of these boreholes.

RESOURCE ESTIMATES

Undiscovered Conventionally Recoverable Resources

Estimates of undiscovered conventionally recoverable resources in the Federal offshore portion of the play have been developed using the subjective assessment method with adjusted onshore analogs (e.g., El Segundo, Playa Del Rey, and Venice Beach fields). Select data used to develop the resource estimates are shown in appendix C.

As a result of this assessment, the Federal offshore portion of the play is estimated to contain 38 MMbbl of oil and 16 Bcf of associated gas (mean estimates). This volume of undiscovered conventionally recoverable resources may exist in as many as 13 pools with sizes ranging from approximately 290 Mbbl to 30 MMbbl of combined oil-equivalent resources (fig. 92). The low, mean, and high estimates of resources in the play are listed in table 26.

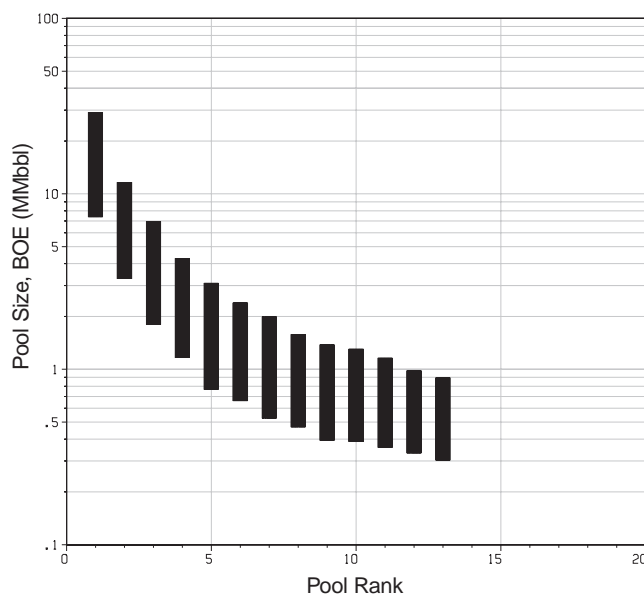


Figure 92. Pool-size rank plot of estimated undiscovered conventionally recoverable resources of the San Onofre Breccia play, Los Angeles Basin province. Sizes of undiscovered pools are shown by bars; the top and bottom of a bar represent the 25th- and 75th-percentile values of a probability distribution, respectively.